

## Early Cretaceous Freshwater Fishes from Northern Kyushu, Japan

### I. Description of Two New Species of the Clupeid Genus *Diplomystus*

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An abundance of fish fossils were discovered from a freshwater bed of Neocomian age, Early Cretaceous, in Kitakyushu City in the northern part of Kyushu Island, Japan. Fish fossil fragments were first uncovered by Professor Y. OTA who was investigating the geology of northern Kyushu (OTA, Y., 1957; 1960) and was later brought to my attention. In 1975, more specimens were found by students of Mr. SOTSUKA (Kokura Senior High School) and were brought to Dr. M. OTA who has since organized later excavations of the fossil fish site.

The locality which yielded the fish fossils is at the edge of a former military arsenal. It occupies a hilly area of about 6 km<sup>2</sup> and is situated at the northeastern end of the Fukuchi Mountain Group in the northern part of Kokura district, in Kitakyushu City. Freshwater deposits of a large Early Cretaceous lake, Kowakino-ko, are widely distributed in the area. The geology of the fossil yielding locality is described in detail by M. OTA and others (1979).

In 1976 and 1977, excavations of the fossil fish sites were conducted by a team of geologists and paleontologists, sponsored by the city of Kitakyushu. As a result, numerous fragments of several species of teleostean fishes belonging to the primitive families Clupeidae and Lycoperidae were collected, along with freshwater crustacea of the family Esteridae and a colony of blue-green algae (ISHIJIMA, 1978, 1979). Specimens are preserved in the Kitakyushu Museum of Natural History (KMNH) collection.

#### Locality

130°51'46"E, 33°51'11"N. Kumagaya 4-chome, Kokura-kita-ku (Northern Ward), Kitakyushu City, Fukuoka Prefecture, Japan. The fossil fish site is located on a cliff about 100 m northeast of the front gate of the former military arsenal.

**Horizon**

Neocomian, Early Cretaceous. The upper layer (fourth layer) of the Wakino-subgroup, Kanmon-group. Paleolake, Kowakino-ko lake deposit. Thickness of the layer which yielded the fish fossils is about 3.6 m and is situated about 10 m above the lowest border of the fourth layer. Fish fossils are found in weathered siliceous shale which appears yellowish-white, yellowish-gray or reddish-yellow in color.

Class Osteichthyes

Subclass Actinopterygii

Superorder Teleostei

Order Clupeiformes

Family Clupeidae

Genus *Diplomystus*

*Diplomystus primotinus* sp. nov.

(Figs. 1-3, Pl. 1)

Holotype. KMNH VP100,001, a nearly complete fish, collected by the excavation team of Kitakyushu City on May 5, 1976.

Paratypes. KMNH VP100,002, anterior half of fish with complete head. KMNH VP100,003, anterior two-thirds, anterodorsal end of the head missing. KMNH VP100,004, posterior three-fourths, lacking head. KMNH VP100,005, anterior two-thirds. KMNH VP100,006, complete fish but some parts are eroded. KMNH VP100,007, posterior four-fifths, with anterior part of head missing. KMNH VP100,008, posterior three-fourths, without head. KMNH VP100,009, posterior three-fourths, without head. KMNH VP100,010, about half, middle portion of fish. KMNH VP100,011, anterior two-thirds, with minute lower jaw teeth. KMNH VP100,012, anterior four-fifths. KMNH VP100,013, anterior four-fifths. KMNH VP100,014, almost complete fish, lacking a small portion of head. KMNH VP100,015, anterior two-thirds.

Other materials. KMNH VP100,016~VP100,030 from the same locality where the holotype was collected.

**Diagnosis**

This new species differs from other members of the genus in having the following characters. The predorsal scutes are oval in shape with rounded

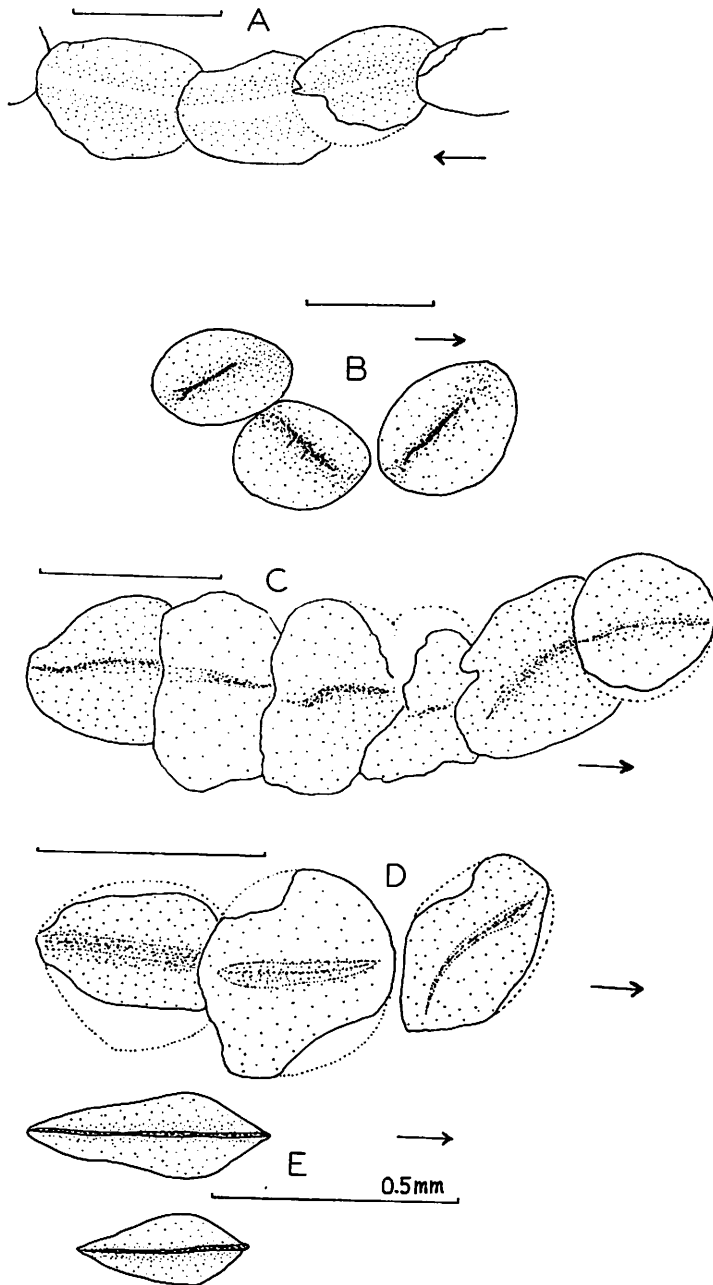


Figure 1. Predorsal scutes. A and B, *Diplomystus primotinus* sp. nov. (KMNH VP 100,001 and KMNH VP100,006). C and D, *Diplomystus kokuraensis* sp. nov. (KMNH VP100,033 and KMNH VP100,031). E, *Hyperlophus vittatus*.

anterior and posterior ends (Fig. 1, A and B), as opposed to pointed or concave ends. The body depth is about one-fourth of the standard length. The head length is about one-third of the standard length.

The number of dorsal pterygiophores is 11 to 12 and anal fin pterygiophores is 24 to 25. The total number of vertebrae is 37 with 20 abdominal and 17 caudal vertebrae. The number of ventral scutes is 18 to 19 in total, with 10 to 11 scutes between the pectoral and pelvic fins, and 7 to 9 scutes between the pelvic and anal fins. The number of predorsal interneural spines is 7.

**Description of the holotype.** The body is slender and the body depth is included 4.2 times in the standard length. The head length is included 3.4 times in the standard length. The dorsal fin is situated at about the middle of the body, and the pelvic fin, below the dorsal fin. The pectoral fin is situated near the ventral edge of the body at the posteroventral corner of the head. The number of dorsal fin pterygiophores is 12. The base of the anal fin is long with 24 pterygiophores. (The number of pterygiophores is usually equal to the number of principal\* dorsal or anal rays in the closely related Recent species, *Hyperlophus vittatus* CASTELNAU) Seven predorsal scutes are visible. The ventral scutes are well-developed and total 19 in number, with 11 scutes between the pectoral and pelvic fins, and 8 scutes between the pelvic and anal fins. The total number of vertebrae is 37, with 20 abdominal and 17 caudal vertebrae. Seven predorsal interneural spines are present. The neural spines of the first to the 15th vertebrae are divided into two. The intermuscular bones are well-developed, especially in the caudal region. The number of predorsal interneural spine is 7. At least 2 epurals are visible. One parhypural and 6 hypural bones are present.

**Description of the paratypes.** Measurements and counts of the holotype and one of the paratypes are presented in Table 1. Characters not presented in the Table are mostly similar to the holotype.

**Etymology:** *primotinus* means primitive or early, which refers to the fact that this species represents one of the earliest and most primitive species of the genus.

*Diplomystus kokuraensis* sp. nov.

(Figs. 1-3, Pl. 2)

**Holotype.** KMNH VP100,031, a nearly complete fish, collected by the excavation team of Kitakyushu City on May 12, 1977.

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\* Small rudimental, unbranched rays in front of the 1st long unbranched ray are not counted.

Paratypes. KMNH VP100,032, almost a complete fish, lacking the anterior tip of head and the caudal fin. KMNH VP100,033, anterior half, well preserved. KMNH VP100,034, anterior two-thirds, with well preserved mouth parts. KMNH VP100,035, posterior two-thirds, with well preserved caudal skeleton. KMNH VP100,036, three-fourths, without the anterior half of head and caudal region. KMNH VP100,037, nearly complete, but some parts are eroded. KMNH VP100,038, anterior two-thirds, lacking a part of the predorsal region. KMNH VP100,039, nearly complete, but anterodorsal part of the head missing. KMNH VP100,040, anterior half. KMNH VP100,041, one-third, with well preserved head region. KMNH VP100,042, anterior two-thirds. KMNH VP100,043, anterior half, well preserved. KMNH VP100,044, anterior two-thirds, with some eroded parts. KMNH VP100,045, anterior half, with well preserved predorsal scutes.

Other materials. KMNH VP100,046~KMNH VP100,070 from the same locality where the holotype was collected.

#### Diagnosis

This species differs from other members of the genus in having the following characters. The predorsal scutes are round in shape and their lengths are almost equal to or shorter than their widths. The anterior and posterior ends of the scutes are round, as opposed to pointed or concave (Fig. 1, C and D). The body depth is about half of the standard length. The head length is about one-third of the standard length. The number of dorsal fin pterygiophores is 11 to 12. The number of anal fin pterygiophores is 20 to 22. The total number of vertebrae is 36, with 20 abdominal vertebrae and 16 caudal vertebrae. The ventral scutes are well-developed, and their number is 17 to 18, with 9 scutes between the pectoral and pelvic fins, and 8 scutes between the pelvic and anal fins. The number of predorsal interneural spines is 7. The intermuscular bones are well developed.

**Description of the holotype.** The body is thick and the body depth is included 1.9 times in the standard length. The head length is included 3.4 times in the standard length. The dorsal fin is situated at about the middle of the body, and the pelvic fin, below the dorsal fin. The pectoral fin is situated near the ventral edge of the body at the posteroventral corner of the head. The number of dorsal fin pterygiophores is 12, and the number of anal fin pterygiophores is 23. Four predorsal scutes are visible. The ventral scutes are well-developed, totaling 17 in number, with 9 scutes between the pectoral and pelvic fins, and 8 scutes between the pelvic and anal fins. The total number of vertebrae is 32, with 18 abdominal and 14 caudal vertebrae. Seven predorsal interneural spines are present. The neural spines of the first to the 7th vertebrae are divided into two. The intermuscular bones are well-developed. At least 2 epurals are visible. A parhypural and 6? hypurals are

Table 1. Measurements and counts of the specimens  
*Diplomystus primotinus* sp. nov.

Specimen No.	KMNH VP100, 001	KMNH VP100, 002	KMNH VP100, 003	KMNH VP100, 004	KMNH VP100, 005	KMNH VP100, 006
Measurements						
standard length	63					
head length	18.5					15.0
body depth	15.0					10.5
snout length	4.2					
eye diameter	9.5					
caudal ped. depth	10.1					
snout to D.	30.3					
snout to A.	48.0					
snout to P <sub>1</sub>	18.0					
snout to P <sub>2</sub>	36.8					
length of D. base	8.2					
length of A. base	10.5					
Counts						
D. pterygiophores	12	12	12	12		12
A. pterygiophores	24		24	pt. 25		
P <sub>1</sub>					15	
pred. int. neural spines						
branchiostegals		4				
vertebrae	20+17=37	20+	20+	19+17=36		20+
visible pred. scutes	6	6	5			5
ventral scutes	P <sub>1</sub> ~P <sub>2</sub>	11	10		11	11
	P <sub>2</sub> ~A	8				7
	total	19				18

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KMNH VP100, 007	KMNH VP100, 008	KMNH VP100, 009	KMNH VP100, 010	KMNH VP100, 011	KMNH VP100, 012	KMNH VP100, 013	KMNH VP100, 014	KMNH VP100, 015
12	12	12	11		12			11
25								
				8	7	7	7	
20+	19+	20+			20+	19+		
7	6	10	9					
10								
8						8		
18								

(to be continued next page)

(continued)

*Diplomystus kokuraensis* sp. nov.

Specimen No.	KMNH VP100, 031	KMNH VP100, 032	KMNH VP100, 033	KMNH VP100, 034	KMNH VP100, 035	KMNH VP100, 036
Measurements						
total length	44					
standard length	35.8					
head length	10.5	11.5				
body depth	19.0	20.0				
snout length	2.2					
eye diameter	2.5					
caudal ped. depth	5.4					
snout to D.	17.4					
snout to A.	26.0					
snout to P <sub>2</sub>	18.6					
length of D. base	5.0					
length of A. base	6.2	6.7				
Counts						
D. pterygiophores	12	12	11	12	12	12
A. pterygiophores	20	22			22	24
P <sub>1</sub>						
C.	10+ 9=19				10+ 9=19	
pred. int. neural spines	7	7	7	7		
branchiostegal rays						
vertebrae	20+16=36	20+16=36		20+	+16=?	19+15=34
visible pred. scutes	4		6	6		
ventral scutes	P <sub>1</sub> ~P <sub>2</sub>	9	10	10		10
	P <sub>2</sub> ~A	8	8		8	8
	total	17	18			18

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(continued)

KMNH VP100, 037	KMNH VP100, 038	KMNH VP100, 039	KMNH VP100, 040	KMNH VP100, 041	KMNH VP100, 042	KMNH VP100, 043	KMNH VP100, 044	KMNH VP100, 045
						12.0		
	12							
	27							
						15		
	7	7			7	7	7	7
						4		
	19+	18+15=33				18+		
	8	5				4	6	5
	10	10		10				
	8	8						
	18	18						

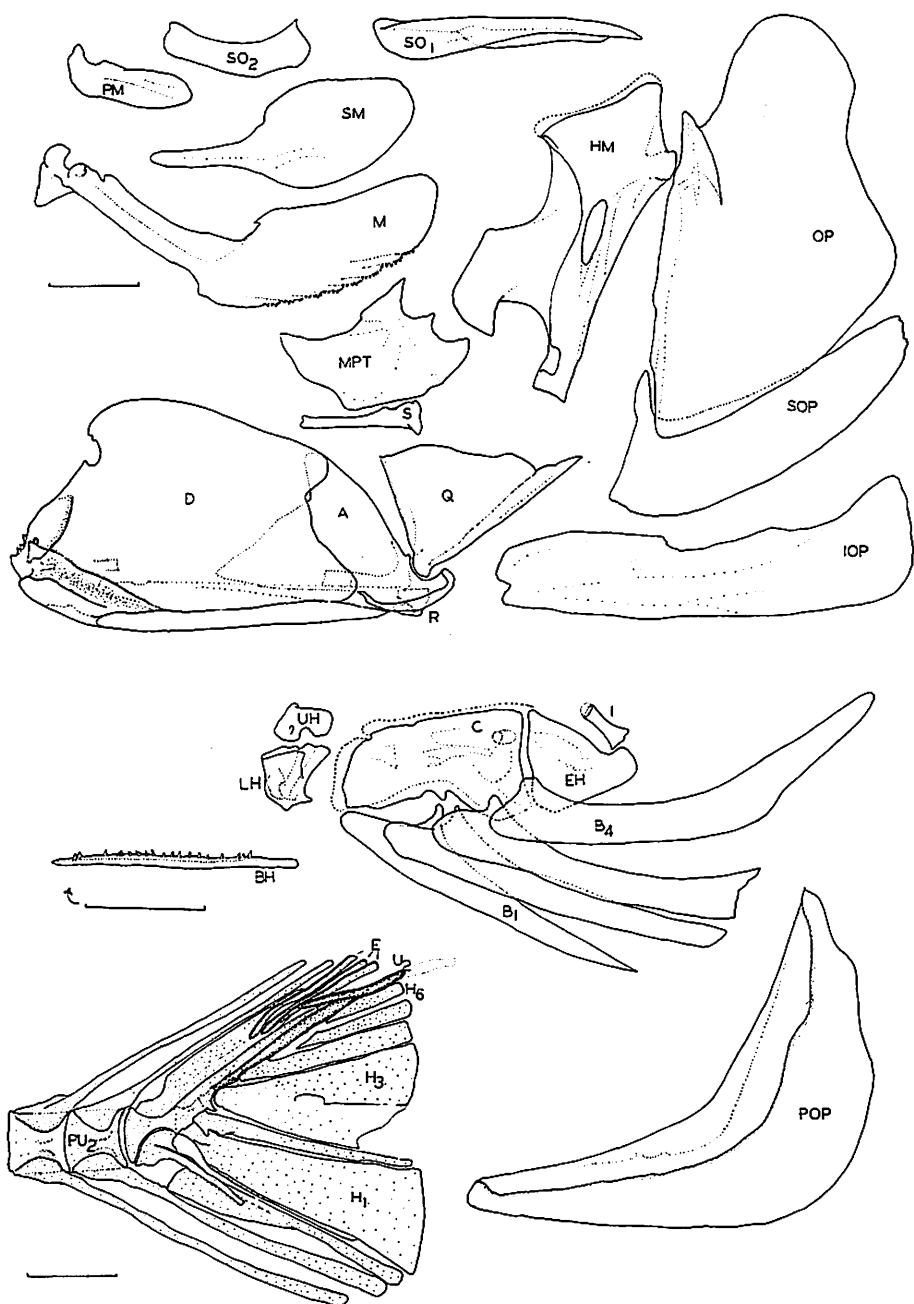


Figure 2. Selected bones of *Hyperlophus vittatus* to be compared with skeletons of *Diplomystus*.

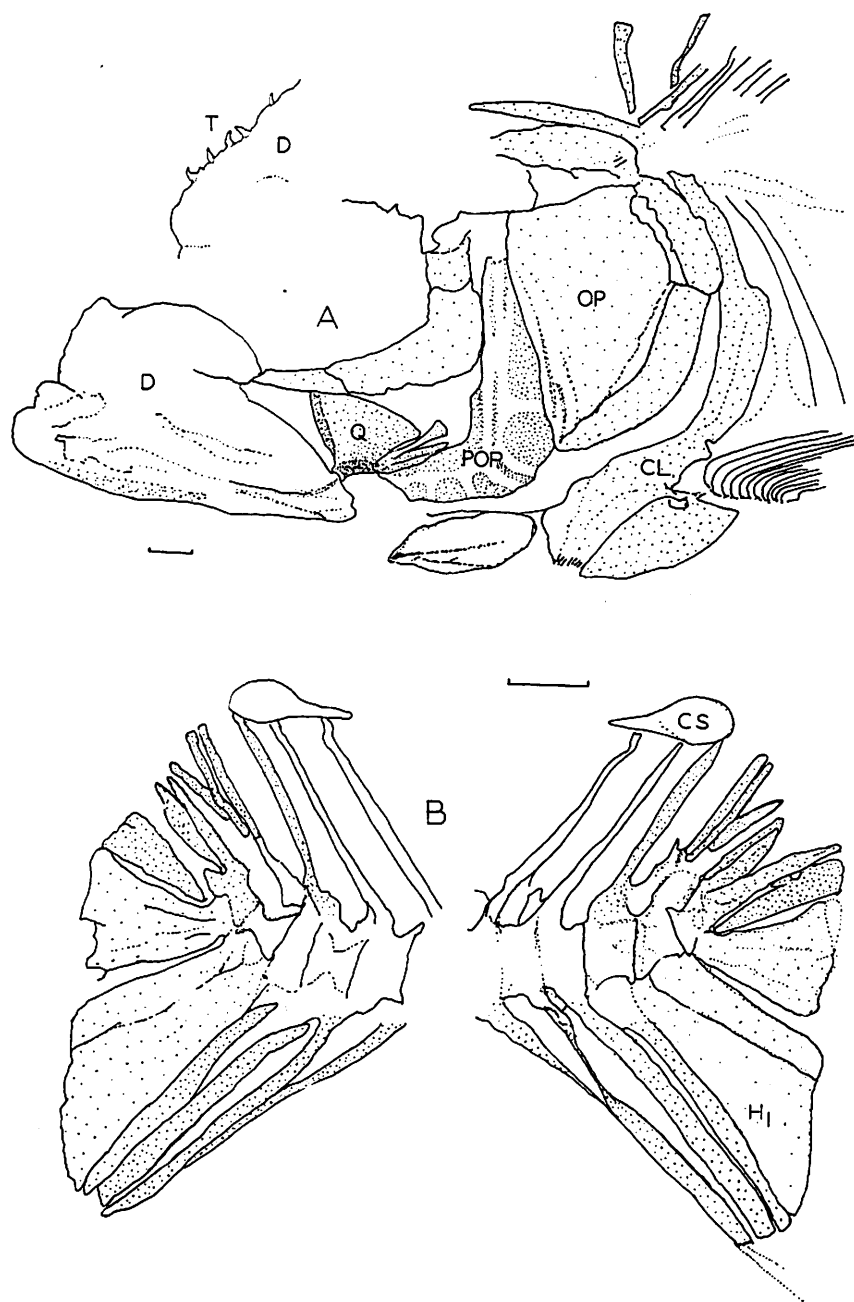


Figure 3. Some observable selected structures of *Diplomystus*. A, *D. primotinus* sp. nov. (holotype, KMNH VP100,001); B, *D. kokuraensis* sp. nov. (KMNH VP100,035).

present.

**Description of the paratypes.** Measurements and counts of the holotype and one of the paratypes are presented in Table 1. Characters not presented in the Table are mostly similar to the holotype.

**Etymology:** *kokura* is the name of the region in Kitakyushu City, which is the type locality of this species.

### Remarks

The genus *Diplomystus* is the oldest member of the double armored herring (see SCHAEFFER, 1947; NELSON, 1970). Among Recent species of the family Clupeidae, *Hyperlophus*, which inhabits Australian waters, has been considered the closest relative of *Diplomystus*. In order to understand the basic osteological structure of the fossil specimens of *Diplomystus*, four specimens of *Hyperlophus vittatus* were cleared and stained for examination. In this species, the first pair of ribs is attached to the third vertebra. The numbers of dorsal and anal pterygiophores usually correspond to the numbers of principal fin rays of the dorsal and anal fins, respectively. Also in this species, the first haemal spine of the caudal vertebra is attached to the posterior side of the first anal pterygiophore. This information is useful in determining the numbers of abdominal and caudal vertebrae, and the numbers of dorsal and anal fin rays in *Diplomystus* fossil material.

The horizon of the locality which yielded the two new species described here is Neocomian, which is one of the oldest beds for species of *Diplomystus*. These two species seem to have the most primitive characters among members of the genus. Predorsal scutes of almost all of the species of *Diplomystus* are either pointed or concave at the anterior and posterior ends, with or without serrations (SCHAEFFER, 1947:22). Recent species of *Hyperlophus* possess predorsal scutes which are pointed at both ends, such as the scutes of *Knightia alta* and *K. eocaena* from Eocene beds of Wyoming. The predorsal scutes of *Diplomystus primotinus* and *D. kokuraensis* described here are round at both ends, which appear to be the most primitive form, since the predorsal scutes must have originated from cycloid scales covering the mid-dorsal line of the predorsal region.

The two new species, *D. primotinus* and *D. kokuraensis* are different in depth of the body and shape of the predorsal scutes, but do not differ in meristic characters and important osteological features. This might indicate that at the age of Neocomian, Early Cretaceous, members of the genus *Diplomystus* were still at the beginning of speciation or diversification, and differentiation of characters took place in the way of relative growth in the fashion described by THOMPSON (1942: 1026~1095). As SCHAEFFER (1947)

stated, it appears that the deeper body is the derived form of the more basic slender form. If this is correct, the deeper bodied species differentiated from the slender bodied forms by faster growth vertically (dorso-ventral direction) and slower growth horizontally (antero-posterior direction). This differentiation must have caused differences in the effectiveness of their movement, which is one of the most important functions in the evolution of teleostean fishes.

### Acknowledgments

I would like to express my sincere appreciation to all the staff members and people connected with the Kitakyushu Museum of Natural History, without whose help, my research would not have been possible. Thanks go especially to Dr. Ryuzo TORIYAMA and Dr. Masamichi OTA for making all the arrangements for the project and for help in collecting specimens. I am also grateful to Dr. Yoshihisa OTA, who first discovered the fish fossils and kindly gave me specimens, and to Mr. Takashi SOTSUKA of Kokura Senior High School who initiated a recent collection of the fish fossils with his students. I am grateful to Dr. Julian PEPPERELL of N.S.W. State Fisheries of Australia who sent me specimens of *Hyperlophus vittatus* from Australia. Dr. Don E. MCALLISTER of the National Museum of Natural Science, Canada, sent me copies of relevant literature. Mrs. Janet M. KRAMER helped with the preparation of the manuscript.

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## Abbreviations

A	articular	M	maxillary
B	branchiostegals	MPT	metapterygoid
BH	basihyal	OP	opercle
C	ceratohyal	PM	premaxillary
CL	cleithrum	POP	preopercle
CS	caudal scute	PU	preural vertebra
D	dentary	Q	quadrate
E	epural	R	retroarticular
EH	epihyal	S	symplectic
H	hypurals	SO	supraorbital
HM	hyomandibular	T	teeth
I	interhyal	U	uroneural
IOP	interopercle	UH	upper hypohyal
LH	lower hypohyal		

Scales in the figures indicate 1 mm.

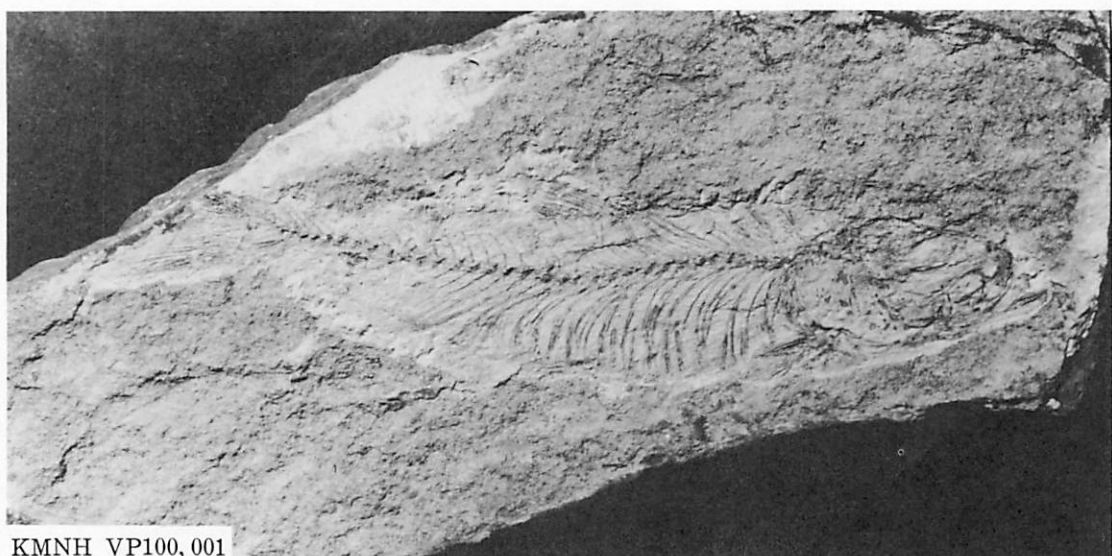
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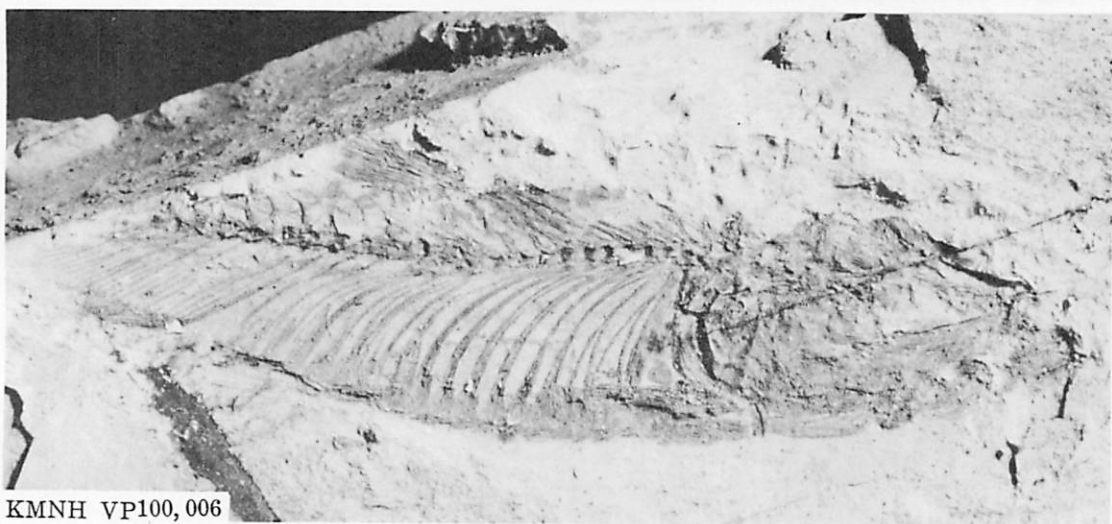
Plate 3-4

### **Explanation of Plate 3**

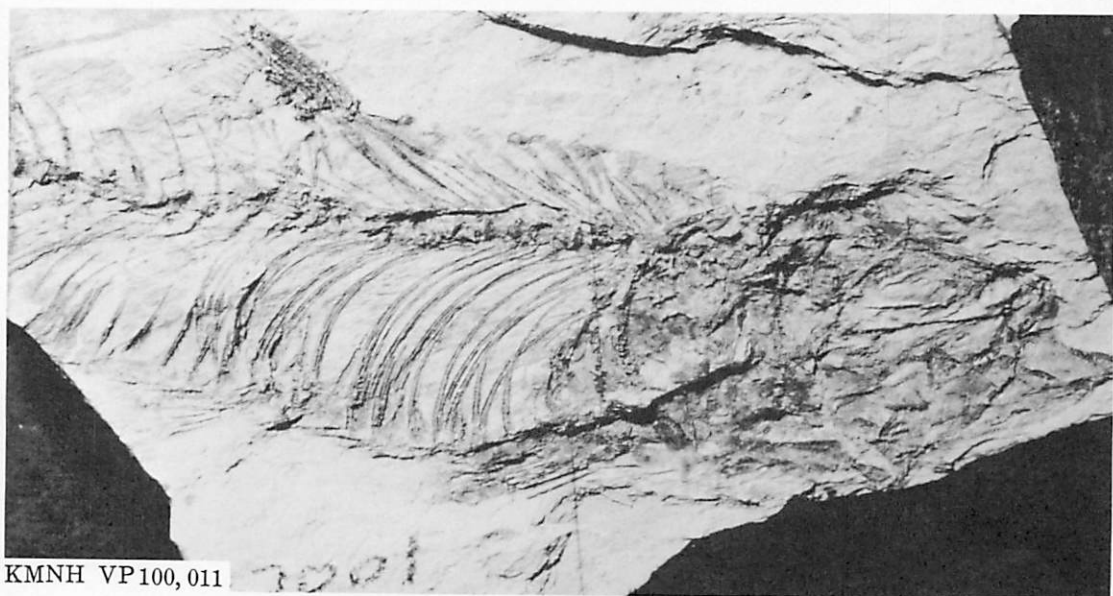
Photographs of *Diplomystus primotinus* sp. nov. Top, KMNH VP100,001; middle, KMNH VP100,006; bottom, KMNH VP100,011.



KMNH VP100,001



KMNH VP100,006



KMNH VP100,011

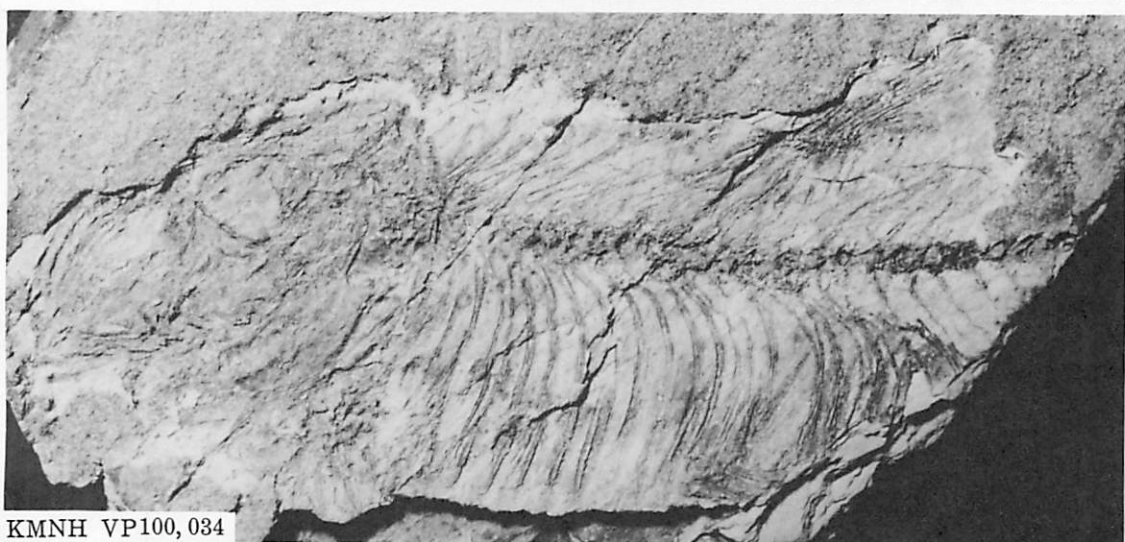
## Plate 4

**Explanation of Plate 4**

Photographs of *Diplomystus kokuraensis* sp. nov. Top, KMNH VP100,031; middle, KMNH VP 100,034; bottom, KMNH VP100,035.



KMNH VP100, 031



KMNH VP100, 034



KMNH VP100, 035